Combination of lidar and model data for studying deep gravity wave propagation

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Reference


Summary and Conclusion

• Missing lidar measurements below 30 km altitude were substituted by mesoscale simulations – enables studies of gravity wave propagation from the troposphere into the mesosphere
• WRF simulations show excellent agreement with local in-situ measurements
• Gravity wave with dominant vertical wavelength of ~9 km detected throughout the entire altitude range
• Wave breaking event around 25–30 km altitude captured by the WRF simulations
• Model fields and radiosonde observations suggest that observed waves are hydrostatic mountain waves

• Observed deep gravity wave propagation from the troposphere into the mesosphere on 3/4 December 2013

Critical horizontal wavelength

• Calculated critical horizontal wavelength from Esrange radiosondes (Fig. 4)
  ➔ Equal to vertical wavelength in case of hydrostatic mountain waves

Fig. 5: Critical horizontal wavelength on 3/4 December 2013

Shift to smaller wavelengths

Similar to Fig. 3b) above 5 km altitude

Wave Analysis for 3/4 December 2013

Vertical structure

• Upward propagating gravity waves
  ➔ Disruption of phase lines
  ➔ Shift to smaller vertical wavelengths – Wave breaking

Fig. 3: a) Temperature perturbations from the combination of lidar measurements and WRF simulations at 3/4 December 2013; b) Corresponding mean wavelet spectrum

• Signatures of gravity waves throughout entire altitude region (Fig. 3a)
• Wave with dominant vertical wavelength ~9 km propagating from the tropopause region into the mesosphere (Fig. 3b)

Horizontal structure

• Region with low winds coincides with turbulence
  ➔ Mountain waves induce a critical layer
  ➔ Leads to wave breaking

Fig. 4: Cross sections through the WRF model on 4 December 0100 UTC
a) horizontal wind speed at 25 km altitude
b) horizontal wind speed along 67.883°N
c) horizontal wind speed along 78.883°N

WRF Validation

• WRF vs Radiosondes: Comparison of temperature perturbations \( T' \) determined from 21 radiosonde launches (Fig. 2):
  - Correlation coefficient: 0.912
  - Root-mean-square error: 0.97 K
• WRF vs Aircraft measurements: Comparison of 5s averaged Falcon in-situ temperature during 3 measurement flights:
  - Root-mean-square error: 0.53 K

Fig. 2: Comparison of WRF and radiosonde temperature perturbations in 2 km wide altitude intervals

Motivation

Methodology

• Temperatures determined from the Esrange lidar’s (68°N, 21°E) Rayleigh channel are combined with mesoscale simulations
• Advanced version of the Weather Research and Forecasting (WRF–ARW) model is used (Fig. 1)
• Temperature data is interpolated to the position of the Esrange lidar beam and averaged over the same time spans
• WRF temperature profiles below 30 km altitude are used to complete missing lidar measurements

Fig. 1: Map of the domains used by the WRF model

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